



Snow Survey and Water Supply Forecasting Program
Montana Data Collection Office

Snowmelt Peak Date Forecasting

Lucas Zukiewicz
Hydrologist

“You can compare one year to another in the mountains, but I can tell you from 30 years of experience, when it comes to snow there is no such thing as average.”

-Craig Skeie, City of Boulder Watershed Manager – when asked about if this is going to be an “average” runoff year by a young ecology graduate student working in an adjacent watershed

Historical Timeline of Montana Snow Surveys

- 1922 – First recorded monthly snow course measurements taken in Montana at Mount Allen #7 and Iceberg Lake #3 in the St. Mary River Basin, now in Glacier National Park, as a joint venture between USGS and Water Survey of Canada.
- During August of 1935, snow courses were established in Wyoming and Yellowstone National Park.
- 1936 Corps of Engineers contributed \$3,000 so that BAE could set up snow courses on the Columbia River basin.
- 1936 the district engineer of the US Geological Survey in Helena coordinated the snow survey measurements for the Missouri River.
- 1964 – First daily snow water equivalent measurements recorded at Lick Creek in the Hyalite Mountains south of Bozeman.

Historical Timeline (continued)

- 1966- First daily reporting site brought on line (line-of-site transmission) in Montana at Shower Falls in the Hyalite Mountains south of Bozeman.
- May 5, 1972 – Maximum snow water equivalent measurement of 94.4” at Bald Eagle Peak snow course, in the Cabinet Mountains. Snow depth was recorded at 176”.
- April 1977 – First SNOTEL radio installed at Lick Creek in the Hyalite Mountains south of Bozeman.
- The Bob Marshall snow survey takes about a week to complete and is about an 80 mile round trip each survey.

2010 Snow Survey and SNOTEL Data Collection Network

CURRENT MONTANA DATA COLLECTION NETWORK

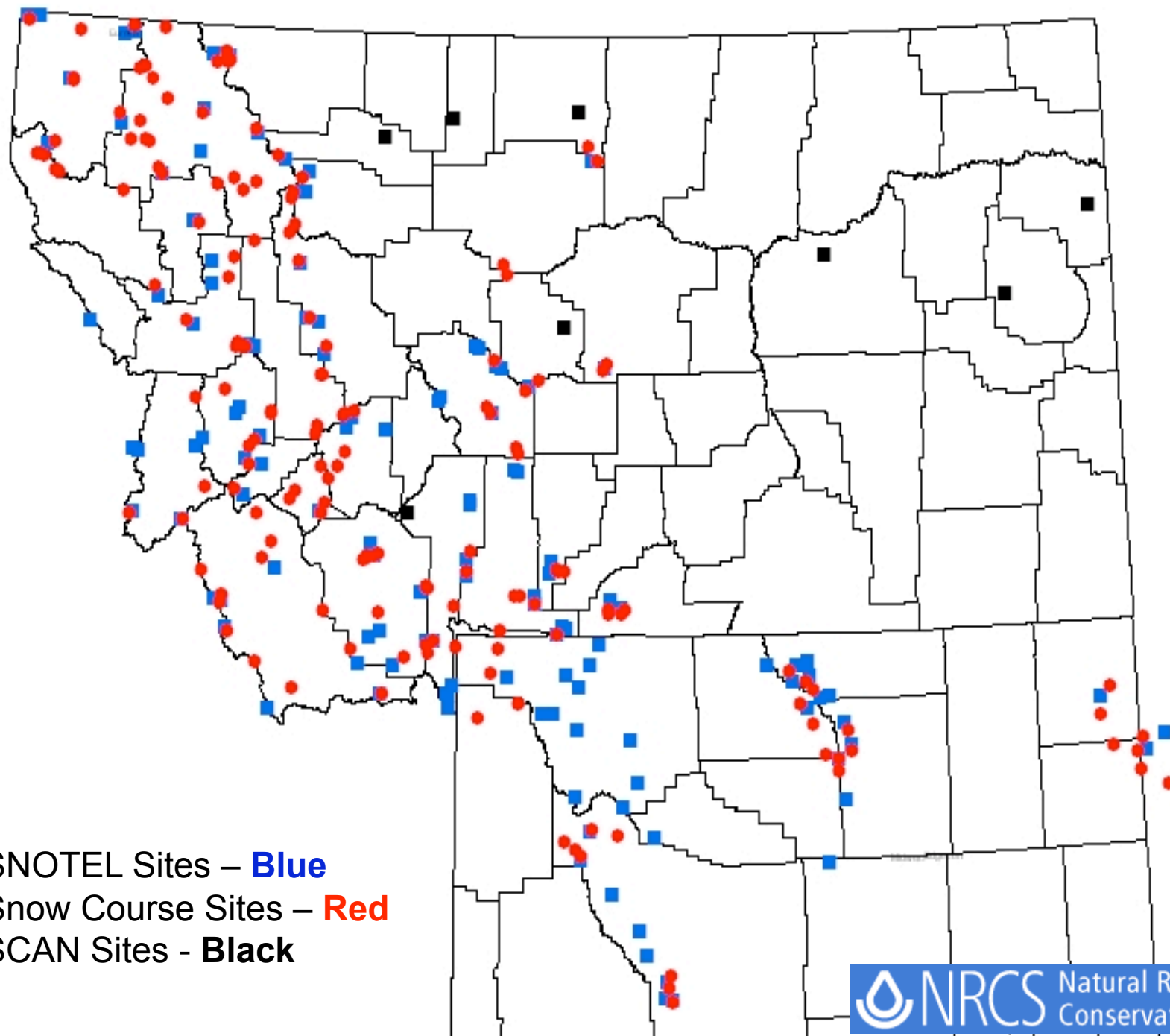
127 SNOTEL Sites (88 in Montana; 37 in Wyoming; 2 in Black Hills of South Dakota) report snow water equivalent, snow depth, precipitation, and temperature data eight times daily. During spring and early summer snow melt period, data collection can be increased to hourly reports to assist local Avalanche Centers, National Weather Service and Alberta Environment, Canada, during flood forecasting and climate monitoring activities.

8 SCAN Sites (Soil Climate Analysis Network) in Montana

170 Snow Courses (142 in Montana; 26 in Wyoming; 2 in Black Hills of South Dakota).

1 NEW SNOTEL site planned for 2010 in Montana

3 NEW SNOTEL sites planned for 2010 in Wyoming



MEASURED PARAMETERS

ALL SITES

SNOW WATER EQUIVALENT (SWE) – Daily Value and Accumulated Through Water Year Snow Pillow and Manual Measurement (SNOTEL and SNOW COURSE)

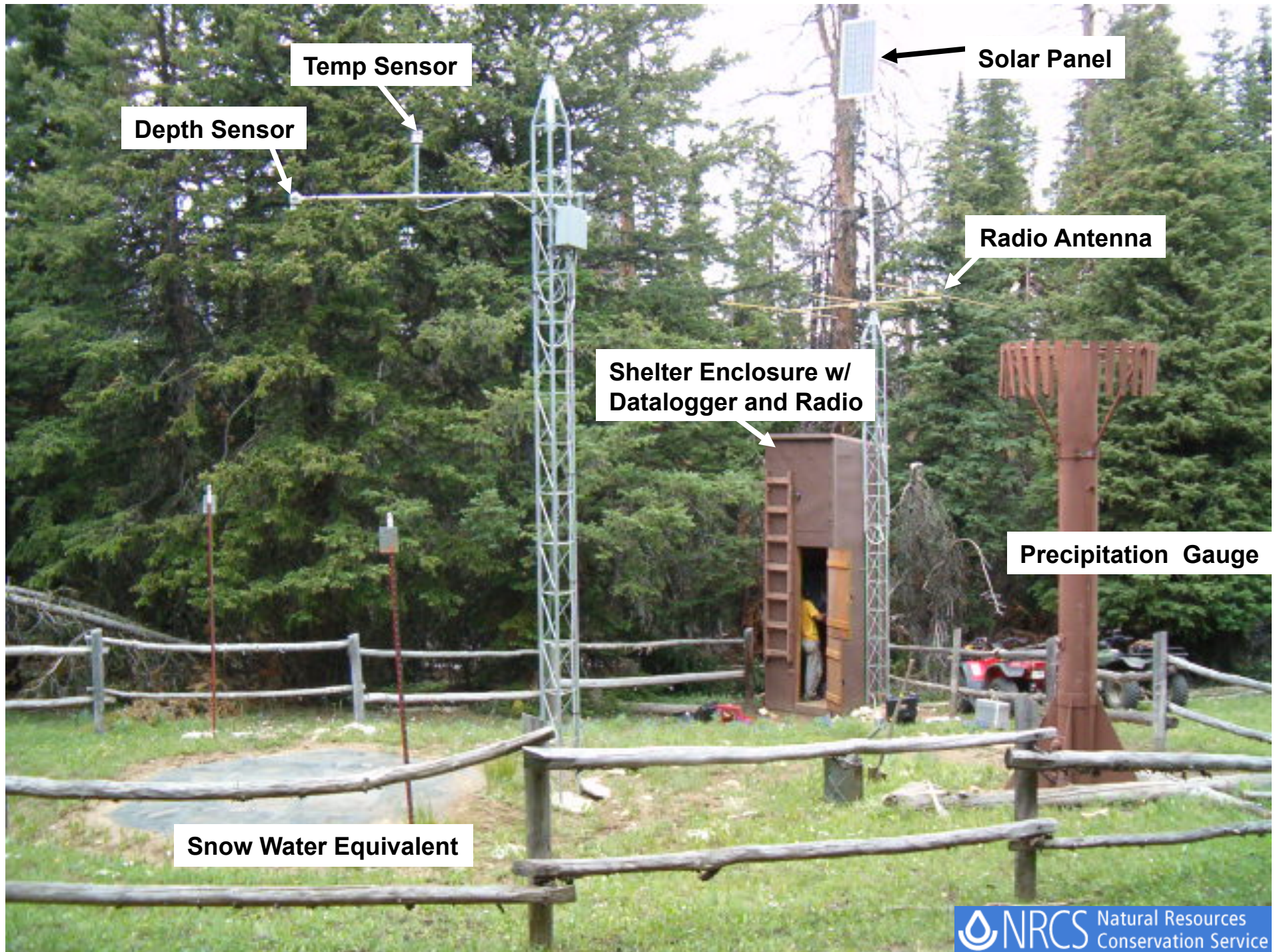
SNOW DEPTH – Daily Value with Snow Depth Sensor and Manual Measurement (SNOTEL and SNOW COURSE)

PRECIPITATION – Daily Total and Accumulated Through Water Year (SNOTEL)

AIR TEMPERATURE – Daily Average, Maximum and Minimum (SNOTEL)

SELECT SITES or COOPERATOR REQUESTS

Relative Humidity, Soil Water Content, Wind Speed, Wind Direction, Solar Radiation.



Temp Sensor

Depth Sensor

Solar Panel

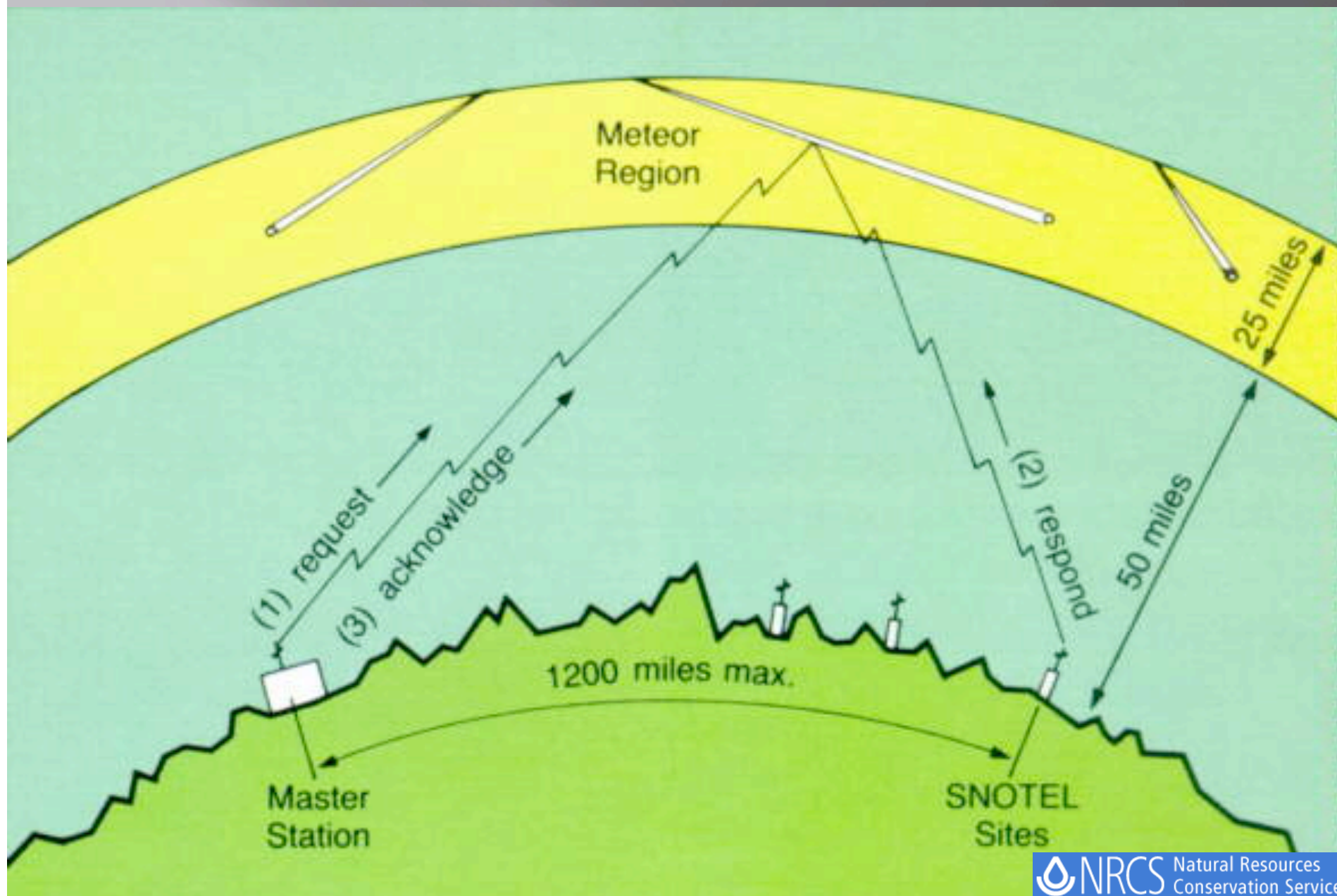
Radio Antenna

Shelter Enclosure w/
Datalogger and Radio

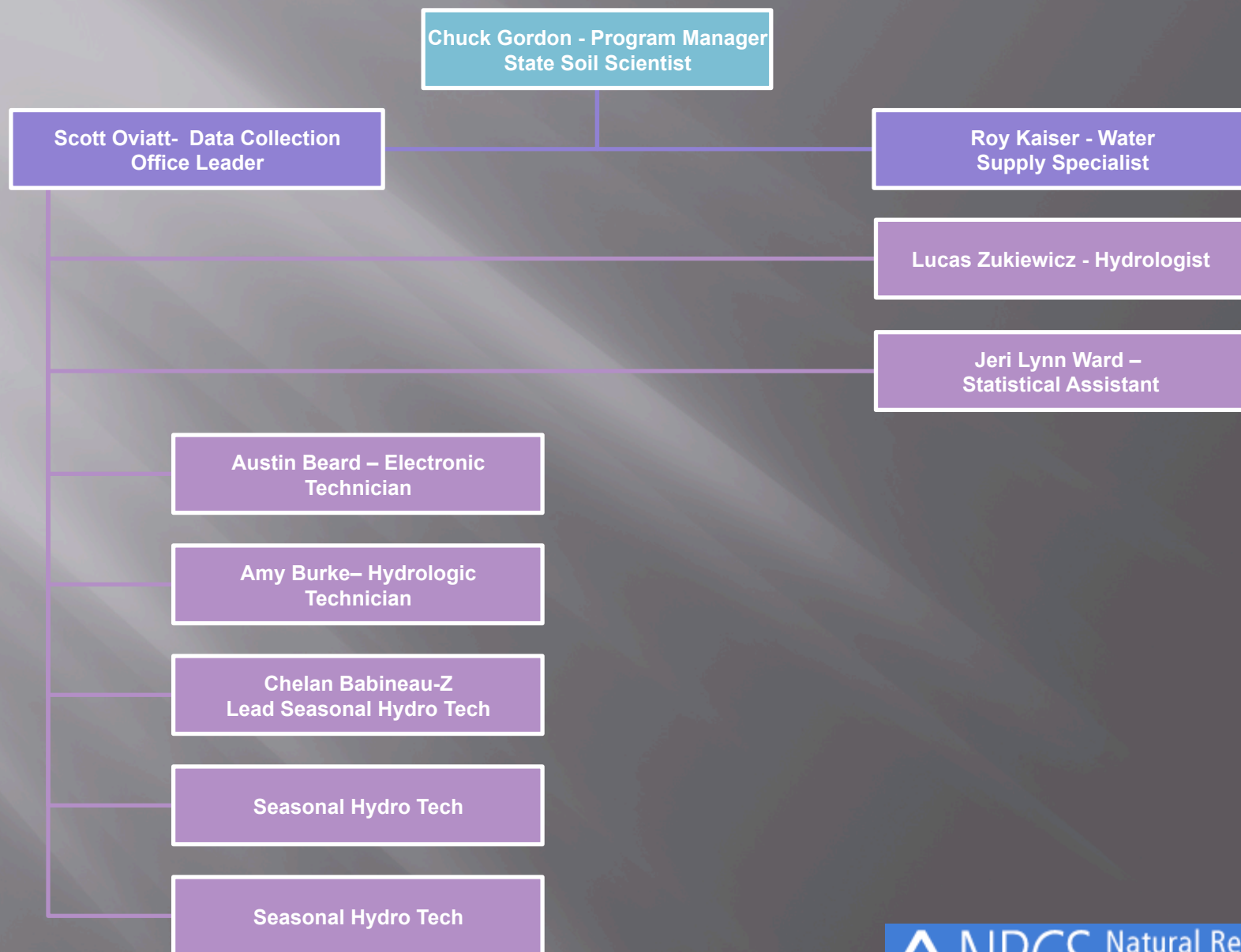
Precipitation Gauge

Snow Water Equivalent

SNOTEL COMMUNICATION USING METEOR BURST TECHNOLOGY



Montana Snow Survey Management Structure



Data Collection and Analysis Duties

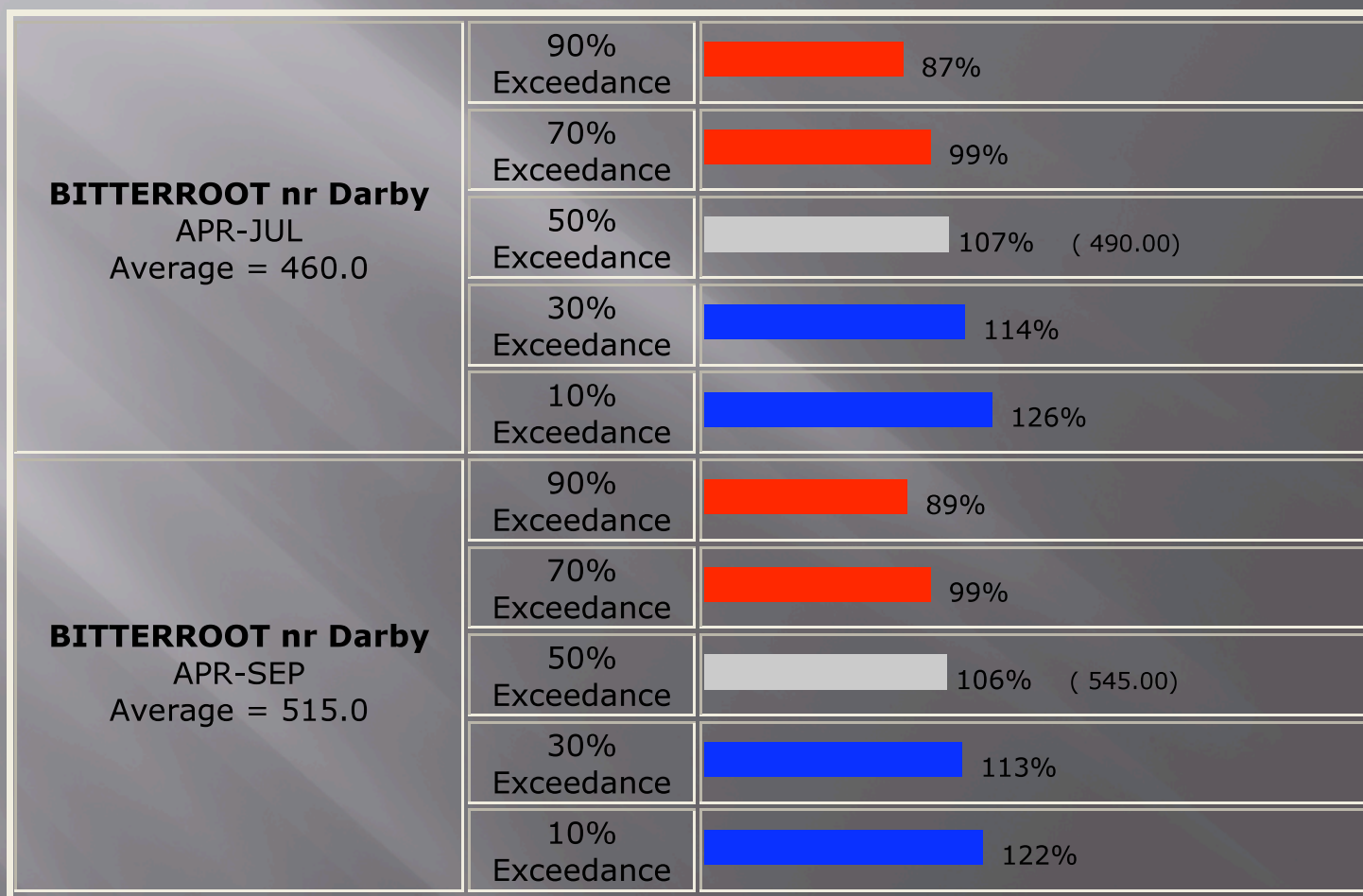
- Snow course data quality control and archival
- Snow course site maintenance
- SNOTEL data quality control, review and archival
- SNOTEL site maintenance
- SNOTEL site emergency repair and equipment removal (Fire)
- Snow data analysis, interpretation, for water supply determinations and forecasting
- Snow and water supply data dissemination to users and general public
- Develop and release state water supply outlook reports
- Handle media contacts and issue state news releases
- Works with state and other federal entities in assessing/mitigating flood and drought conditions

Timeline of Forecasting Operations

- ▣ **Beginning of Water Year (October 1st)**
 - Assess soil moisture conditions going into winter
- ▣ **Winter (December-March)**
 - Monitor and measure snowpack conditions in the mountains via land, air surveys and SNOTEL
- ▣ **Spring (April-July)**
 - 2,060 seasonal volume water supply forecasts are issued at 98 stream gages to water managers and water users of Montana
 - 387 snowmelt peak forecasts are issued annually April through June. These forecast the date and volume of when streams and rivers should crest during the peak snowmelt periods. Snowmelt peak forecasts are used widely by Federal, State, and Local water users and water managers.
 - 154 low flow forecasts are issued for fish biologists, river floaters, irrigators, and local watershed groups so that they can plan in advance and mitigate the potential impacts of critically low streamflows
 - 520 Surface Water Supply Indexes (SWSI's) are produced for 52 individual watersheds in Montana January through October.

SEASONAL VOLUME FORECASTS

2,060 seasonal volume water supply forecasts are issued at 98 stream gages, January through June, to water managers and water users of Montana.



LOW FLOW FORECASTS

154 low flow forecasts are issued for fish biologists, river floaters, irrigators, and local watershed groups so that they can plan in advance and mitigate the potential impacts of critically low streamflows.

Blackfoot River at Bonner updated August 18, 2009

Assuming average precipitation the Blackfoot River should reach 700 cfs between August 25 and August 29.

Assuming below average precipitation, the Blackfoot River should reach 700 cfs between August 20 and August 25.

Assuming well below average precipitation, the Blackfoot River should reach 700 cfs between August 13 and August 20.

This year the river reached 700 cfs on August 17. Last year (2007) the river reached 700 cfs on July 23.

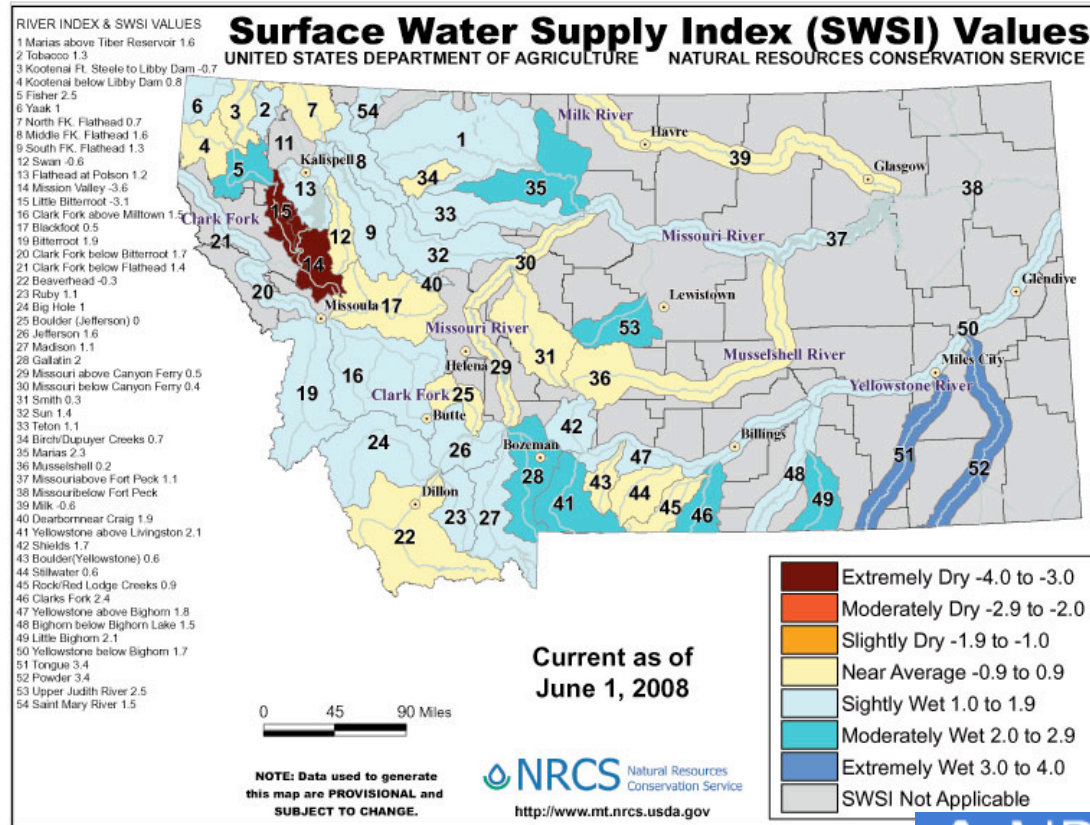
This year the river receded to 2,000 cfs on July 14. Last year the river receded to 2,000 cfs on June 21.

This year the river receded to 1500 cfs on July 19. Last year the river receded to 1500 cfs on June 28.

This year the river receded to 1000 cfs on July 30. Last year the river receded to 1000 cfs on July 8.

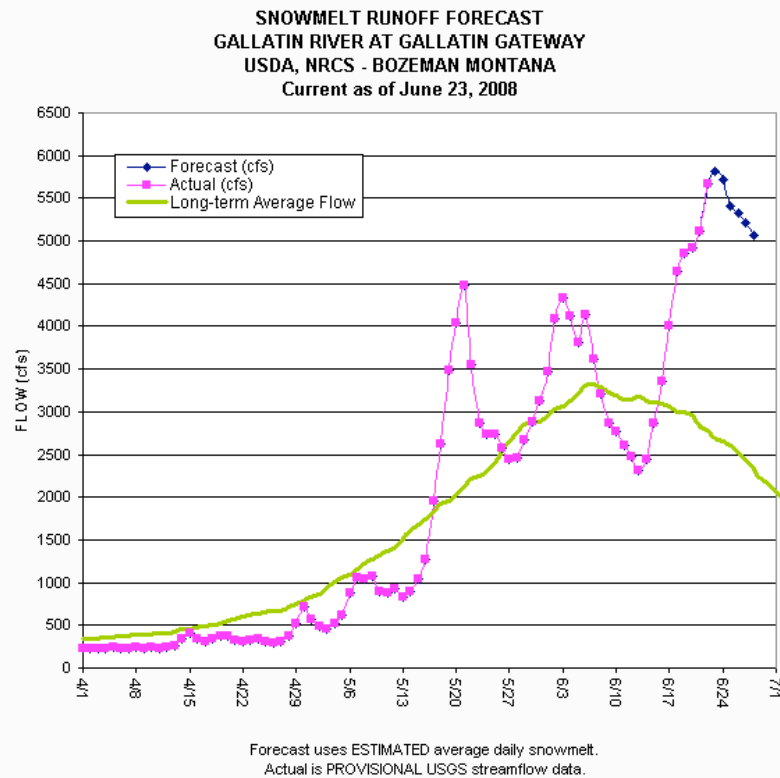
SURFACE WATER SUPPLY INDEX (SWSI)

520 Surface Water Supply Indexes (SWSI's) are produced for 52 individual watersheds in Montana January through October. SWSI's are utilized by the Governor's Drought Advisory Committee, USDA Farm Services Agency, and other state and federal agencies whose drought response is tied directly to SWSI values. During high runoff years, the Montana Disaster and Emergency Services utilizes SWSI's to help identify potential flood areas and mitigate possible flood damages. Montana SWSI's are also used by the National Drought Monitor authors to help determine drought designations in Montana.



SNOWMELT PEAK FORECASTS

387 snowmelt peak forecasts are issued annually April through June. These forecast the date and volume of when streams and rivers should crest during the peak snowmelt periods. Snowmelt peak forecasts are used widely by Federal, State, and Local water users and water managers.



Snowmelt Peak Streamflow Forecasts based on May 1 data.

WATERSHED	PEAK FLOW DATES
COLUMBIA RIVER BASIN	
Bitterroot River near Darby	May 26 to June 8
Blackfoot River near Bonner	May 24 to May 31
Clark Fork River above Missoula	May 27 to June 8
Clark Fork River at St. Regis	May 28 to June 5

Snowmelt peak volume forecasts are computed using May 1 streamflow forecasts.

	PEAK RANGE	% OF AVE	AVE
COLUMBIA RIVER			
Bitterroot near Darby ...	4,900 to 7,600	90 to 139	5,454
Blackfoot near Bonner ...	7,000 to 10,800	82 to 127	8,512
Clark Fork ab Missoula .	13,000 to 19,500	88 to 133	14,698
Clark Fork blw Missoula	25,000 to 37,500	88 to 132	28,482

So how do we come up with our Peak Date forecasts?

Micro Scale-

- Cold Content Calculations (field data intensive)
- Energy Balance Methods (instrument intensive)

Radiation-Melt Graph

$$Q_{\text{melt}} = Q_{\text{net short wave}} + Q_{\text{net long wave}} + Q_{\text{advected sensible}} + Q_{\text{evap condense}} + Q_{\text{ground}} + Q_{\text{rain}} - Q_{\text{stored energy}}$$

Macro Scale-

- NRCS Snow Survey Regression (>30 yrs record; r^2 0.86 usual)

$$\text{Predicted Runoff} = R = a + bB + fF + pP + sS$$

R = Predicted Runoff Volume

B = Base Flow

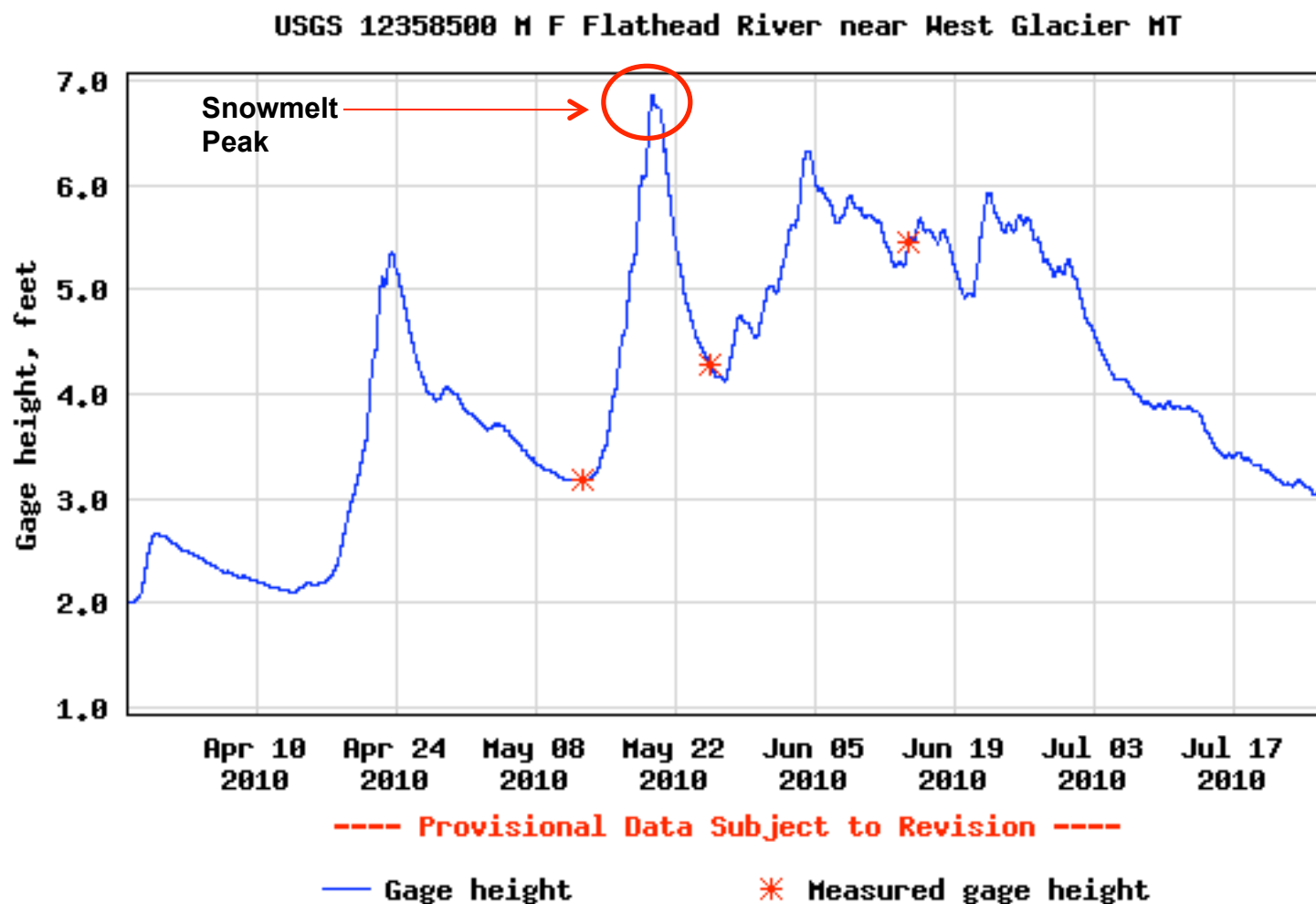
F = Fall Precipitation (Antecedent Moisture)

P = Spring Precipitation

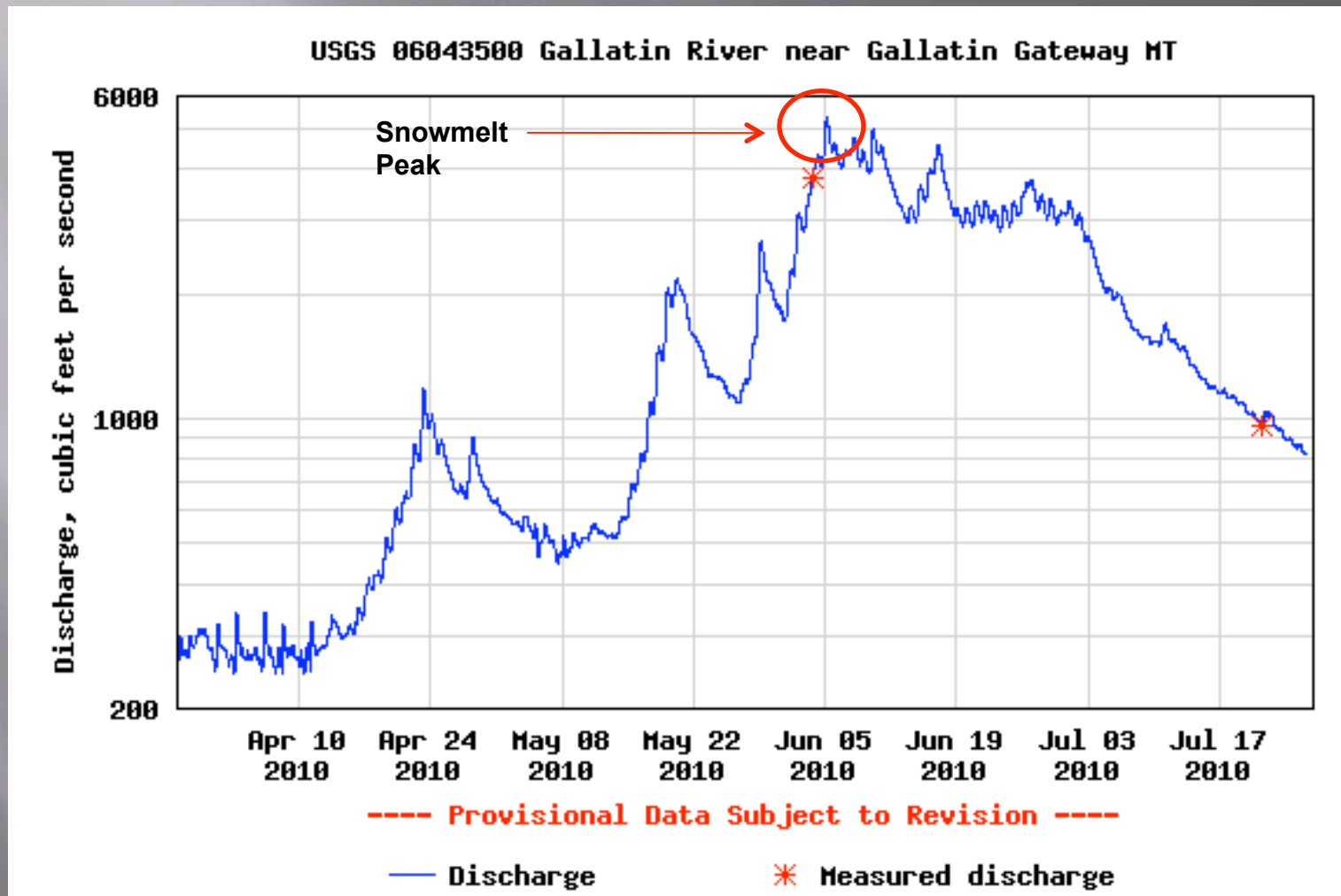
S = Snow water equivalent (April 15)

- SMPA model - Long-Term Regressional Statistics using real-time data
- VIPER model (Statistical Model) - Peak Stream Volumes, Low Flow Volumes
- BLASÉ model (Operational Model) - Peak Snowmelt Date

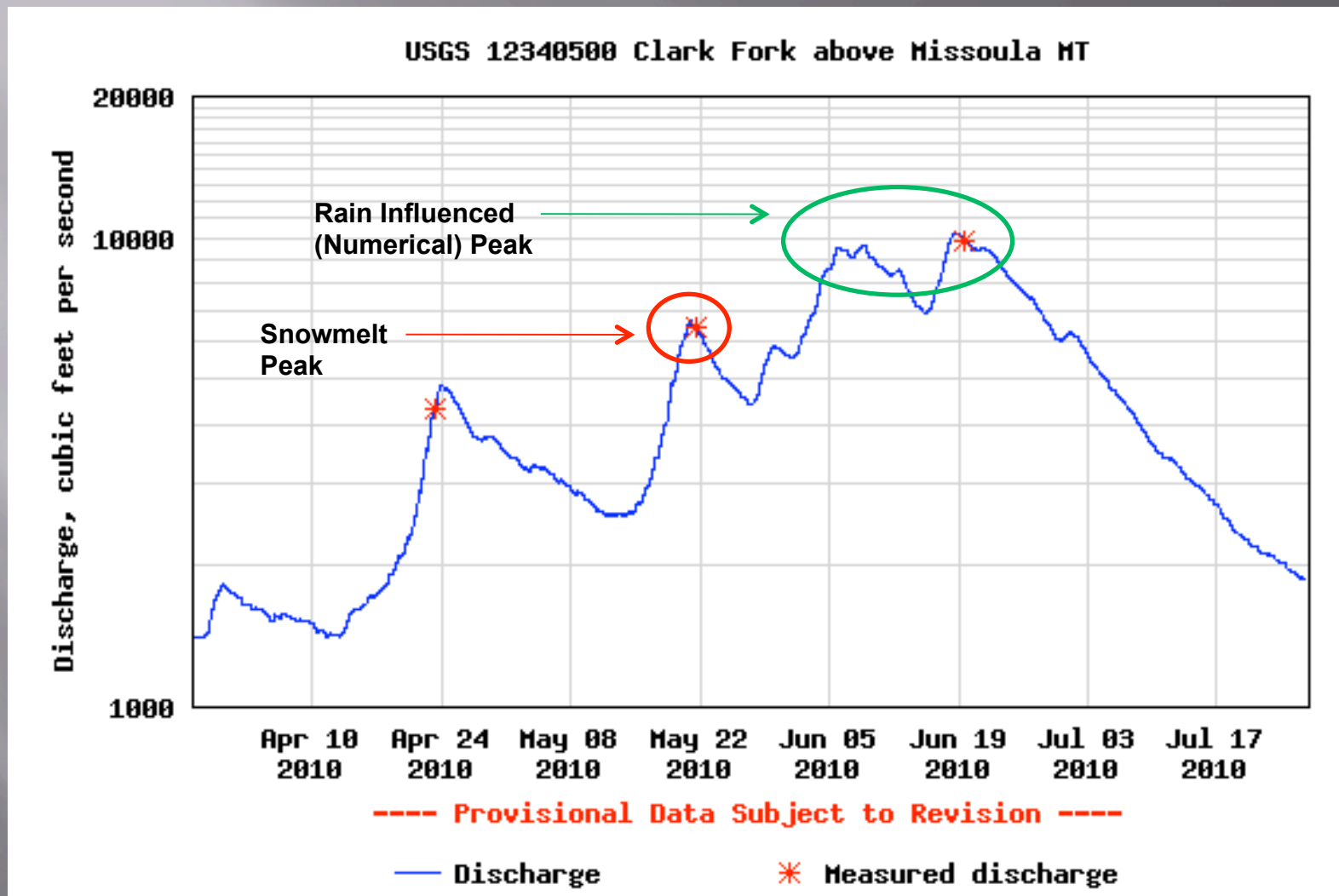
What exactly is the Snowmelt Peak Date?



Sometimes it's straight forward



Sometimes it's not!

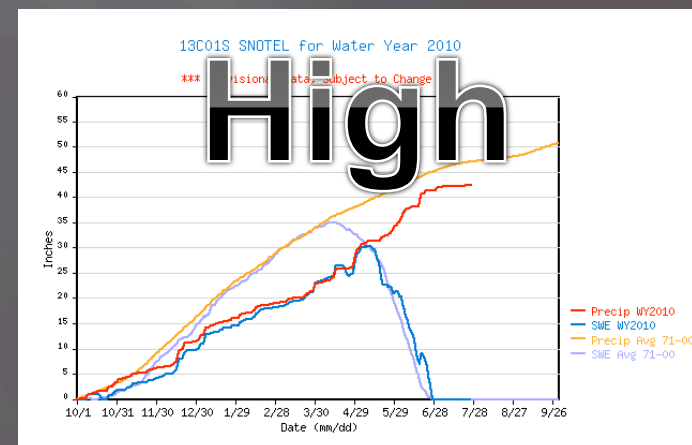
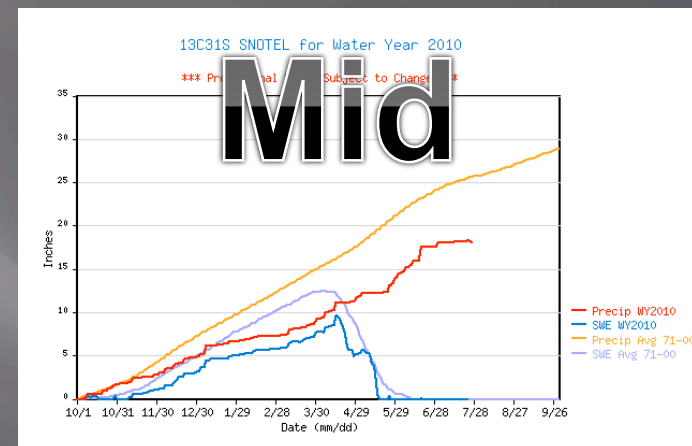
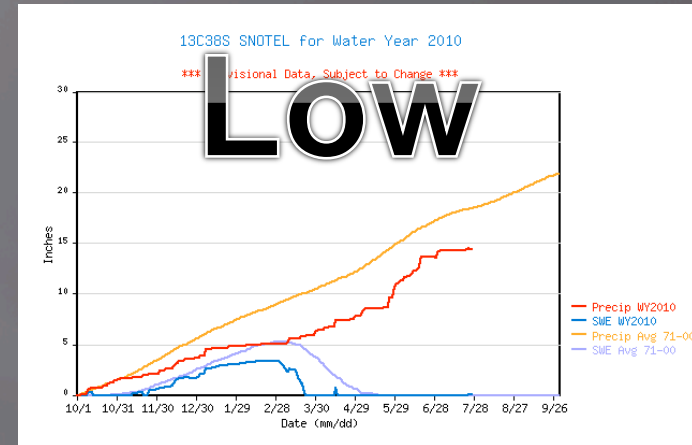


Factors that make Peak Date Forecasting Difficult

- ▣ Soil Moisture Defecits entering Water Year
- ▣ Spatial limitation of data points
- ▣ Forecasting uncertainty in weather patterns
 - Cool/Wet vs Warm/Dry Springs
 - Differential Melting at Elevations in a Watershed early in Winter/Spring.
- ▣ Rain on Snow Events!!!

Verification of Peak Melt Dates

- Comparisons of SNOTEL sites by elevation in a watershed
- Analysis of Current Soil Moisture Conditions
- Daily Monitoring of the Hydrograph
- Model Runs

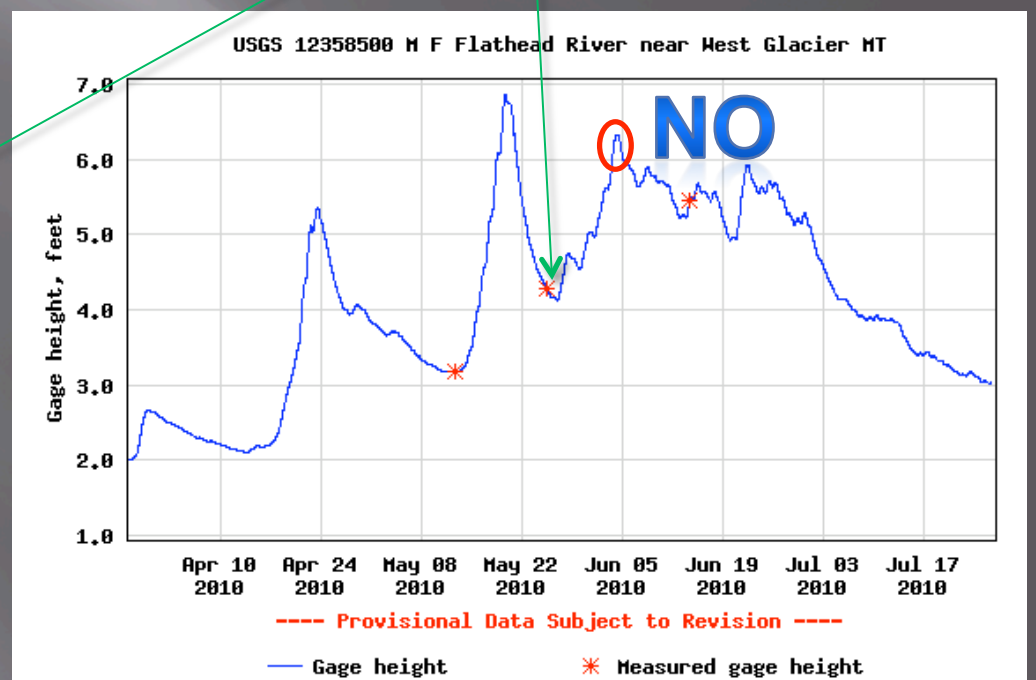
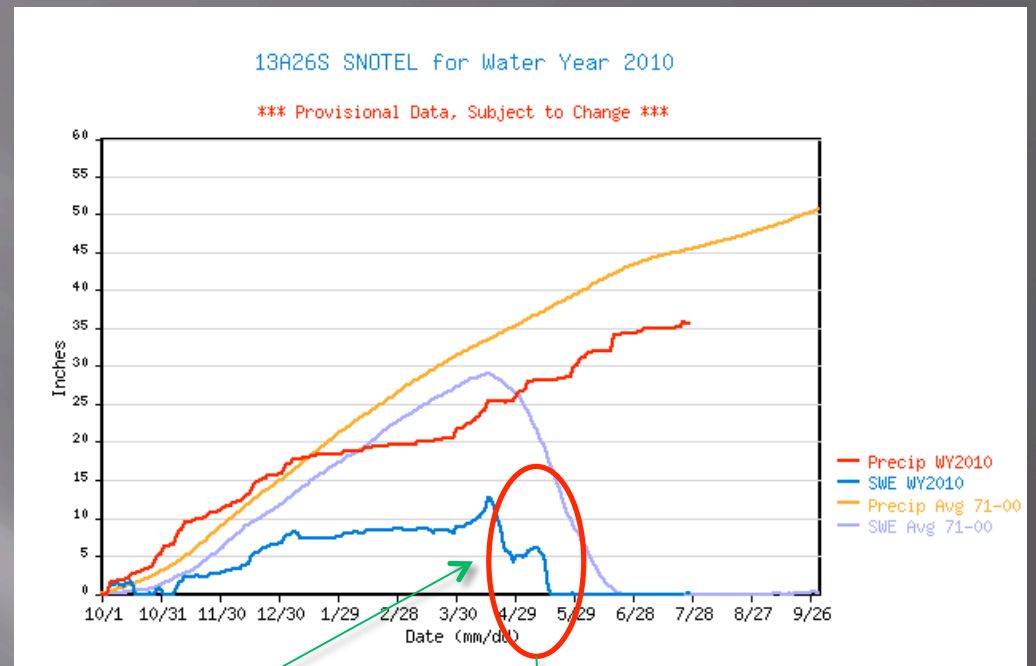


Verification of Peak Melt Dates

During years with multiple peaks in the Hydrograph

The Big Question is:

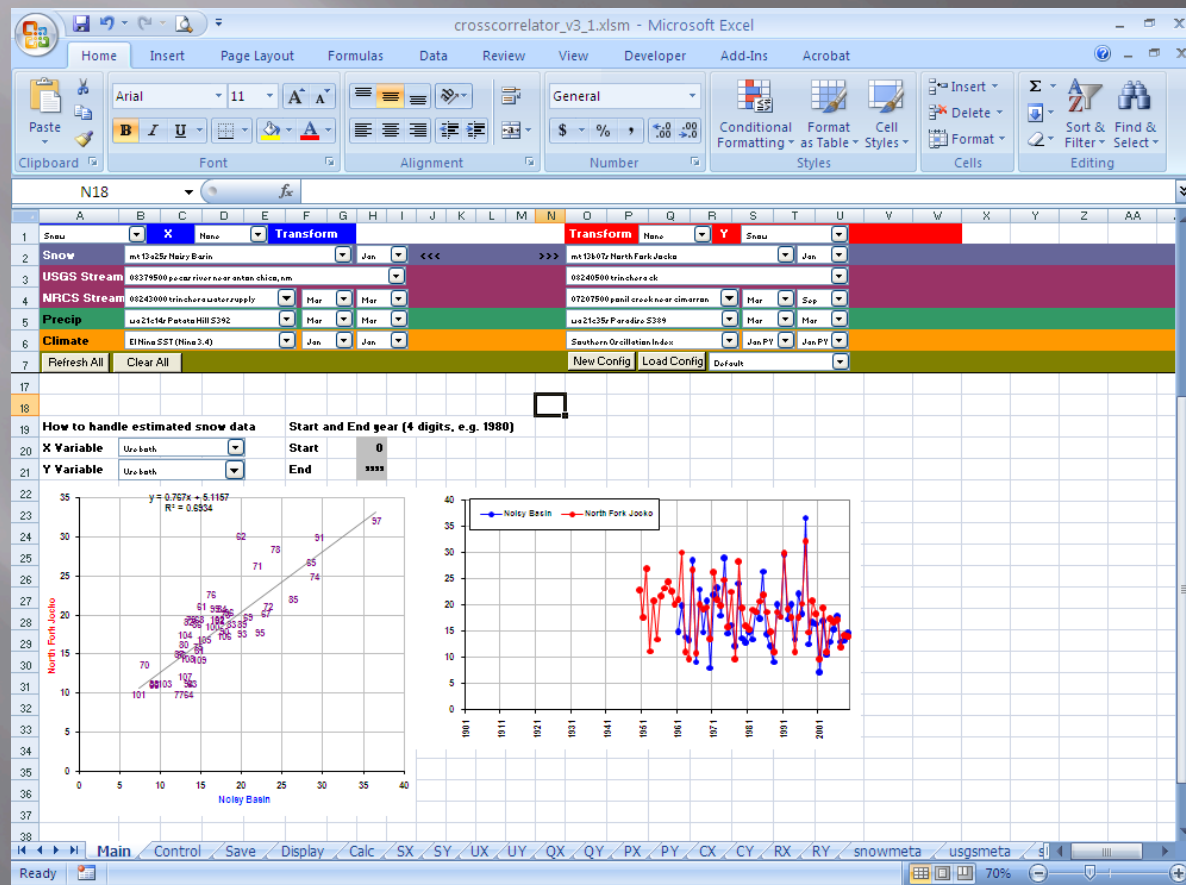
Is there enough available water at your major contributing elevations water for the flows to come back?



FORECASTING TOOLS

Regression/Correlation Tool

The regression tool can be used to compare multiple parameters from a Database to find the correlation between USGS gauged streams, SNOTEL sites, Snowcourses, and climate related data.



SMPA

Gallatin River at Logan MT Peak Flow Date Forecasts

BEAVER CREEK

MAX SWE this year 14.2
CURRENT SWE 13.2
Percent Melt 7%
Melt Curve Used 10%

Today's is: 117
Julian
Early Peak 138
Average Peak 155
Late Peak 172

4/27
Date
5/18
6/4
6/21

[Return to
Menu](#)

BRACKETT CREEK

MAX SWE this year 23.4
CURRENT SWE 17.8
Percent Melt 24%
Melt Curve Used 20%

Today's is: 137
Julian
Early Peak 137
Average Peak 153
Late Peak 169

5/17
Date
6/2
6/18

CARROT BASIN

MAX SWE this year 22.0
CURRENT SWE 21.2
Percent Melt 4%
Melt Curve Used 0%

Today's is: 172
Julian
Early Peak 138
Average Peak 155
Late Peak 172

5/18
Date
6/4
6/21

LICK CREEK

MAX SWE this year 10.9
CURRENT SWE 7.9
Percent Melt 28%
Melt Curve Used 30%

Today's is: 174
Julian
Early Peak 138
Average Peak 156
Late Peak 174

5/18
Date
6/5
6/23

Blazé Model continued

Downloads current data from SNOTEL server

Type of Analytical Technique used

Download Current SWE Data

Averaged Melt Rate based on the last 10 Day(s)

Melt Rate Based on Averaged Melt Rate

Mean Melt Rate Period May 1 - May 15

Which Date's Melt Rate 21-May

Interpolated Date 15-May

System Last Updated On

SMAcPaFFv2A

Calculated, Historical, or Actual Melt Rate

Number of days used in analysis

Forecast Point

SNOTEL sites used in forecast

Forecast Point	Name	Current SWE	Melt Rate	Melt-Out	Estimated Peak Flow Date	Averaged Date	Trimmed Average	Snow Pack Remaining							
Big Hole River Below Big Lake Creek at Wisdom, MT	Darkhorse Lake	8,960	28	25-May	14	12-Feb	3-Nov	28	0.03	1/2 Melt	5-Feb	18-Jun	12-Apr	3-Jun	100%
	Lemhi Ridge	8,100	11.7	13-May	5.85	9-Jul	12-Sep	9.9	-0.1	Melt-Out	23-Sep	11-Jul	12-Apr	3-Jun	85%
	Saddle Mountain	7,900	15.5	15-Apr	7.75	19-Jun	28-Jun	12.9	-0.2	1/2 Melt	24-Jun	17-Jun	12-Apr	3-Jun	83%
	Mule Creek	7,830	15.1	13-May	7.55	28-Jun	28-Jun	14.9	0	1/2 Melt	1-Jul	7-Jun	12-Apr	3-Jun	99%
	Bloody Dick	7,650	8.4	14-Apr	4.2	17-May	30-May	1.9	-0.4	Melt-Out	15-Jun	1-Jun	12-Apr	3-Jun	23%
Big Hole River Below Big Lake Creek at Wisdom, MT	Calvert Creek	6,430	5.8	14-Apr	2.9	22-Apr	24-Apr	0	0	Melt-Out	25-Apr	19-May	12-Apr	3-Jun	0%
	Darkhorse Lake	8,960	28	25-May	14	12-Feb	3-Nov	28	0.03	1/2 Melt	3-Feb	30-Jul	25-Apr	1-Jun	100%
	Lemhi Ridge	8,100	11.7	13-May	5.85	9-Jul	12-Sep	9.9	-0.1	Melt-Out	18-Sep	21-Jul	25-Apr	1-Jun	85%
	Saddle Mountain	7,900	15.5	15-Apr	7.75	19-Jun	28-Jun	12.9	-0.2	1/2 Melt	17-Jun	11-Jun	25-Apr	1-Jun	83%
	Mule Creek	7,830	15.1	13-May	7.55	28-Jun	28-Jun	14.9	0	1/2 Melt	29-Jun	4-Jun	25-Apr	1-Jun	99%
Big Hole River Below Big Lake Creek at Wisdom, MT	Bloody Dick	7,650	8.4	14-Apr	4.2	17-May	30-May	1.9	-0.4	Melt-Out	7-Jun	28-May	25-Apr	1-Jun	23%
	Calvert Creek	6,430	5.8	14-Apr	2.9	22-Apr	24-Apr	0	0	Melt-Out	11-Jun	2-Jun	25-Apr	1-Jun	64%
	Darkhorse Lake	8,960	28	25-May	14	12-Feb	3-Nov	28	0.03	1/2 Melt	12-Oct	11-Sep	20-Mar	24-May	95%
	Lemhi Ridge	8,100	11.7	13-May	5.85	9-Jul	12-Sep	9.9	-0.1	1/2 Melt	24-May	20-May	20-Mar	24-May	35%
	Saddle Mountain	7,900	15.5	15-Apr	7.75	19-Jun	28-Jun	12.9	-0.2	1/2 Melt	29-Dec	18-Mar	20-Mar	24-May	100%

Current SWE value to project forward

Model Output for Peak Date

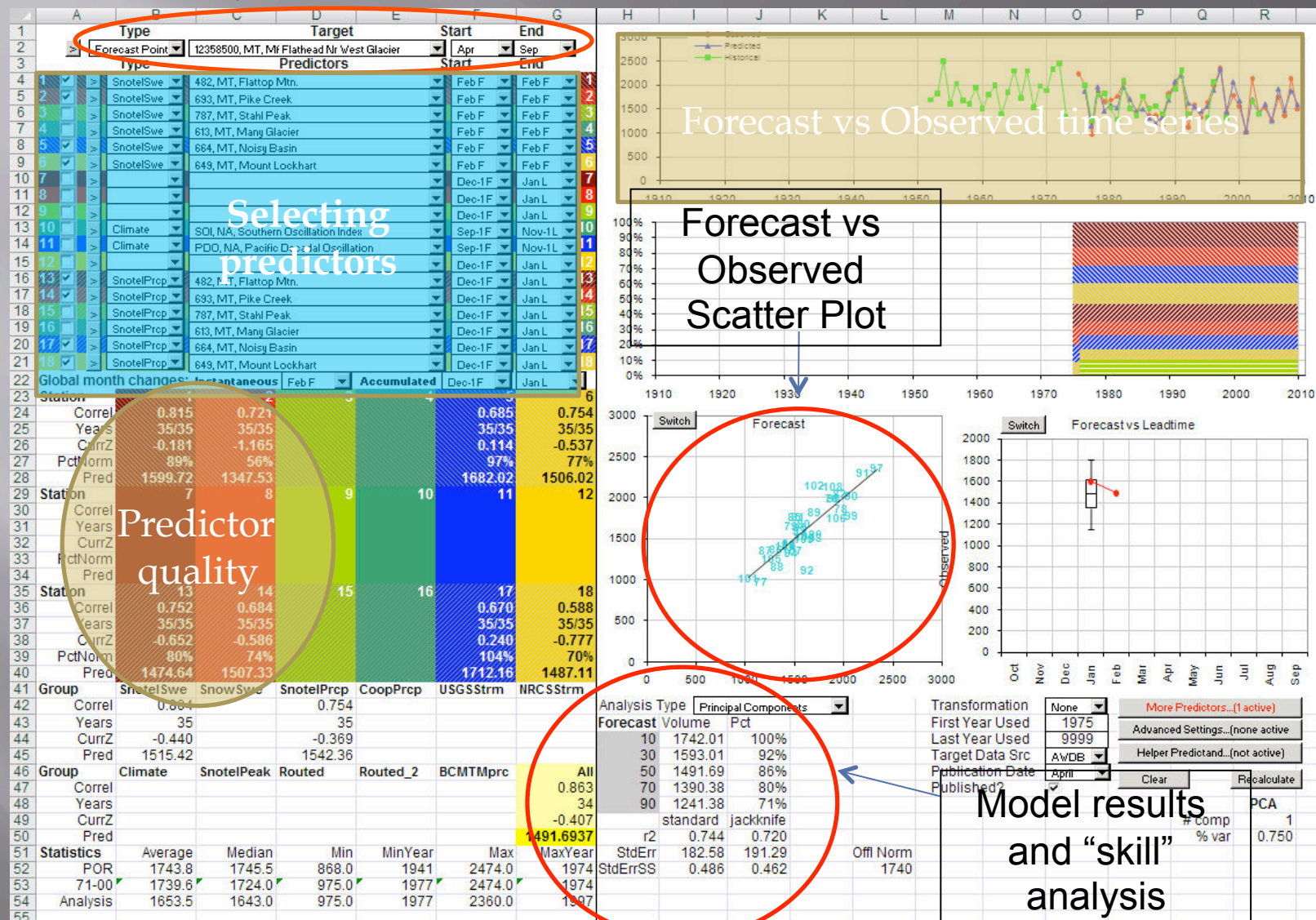
Trimmed Average Date excluding outliers

Blazé Model continued

- ▣ Still in development phase by the Montana DCO
- ▣ Shows promise for narrowing a date range for a forecast point over SMPA
- ▣ Integration of Historical data with real-time data allows user anticipation of weather and climate related variables in snow melt
- ▣ Will integrate predictor quality in future versions.

Target

The Viper Platform



Peak Date Forecasts Online

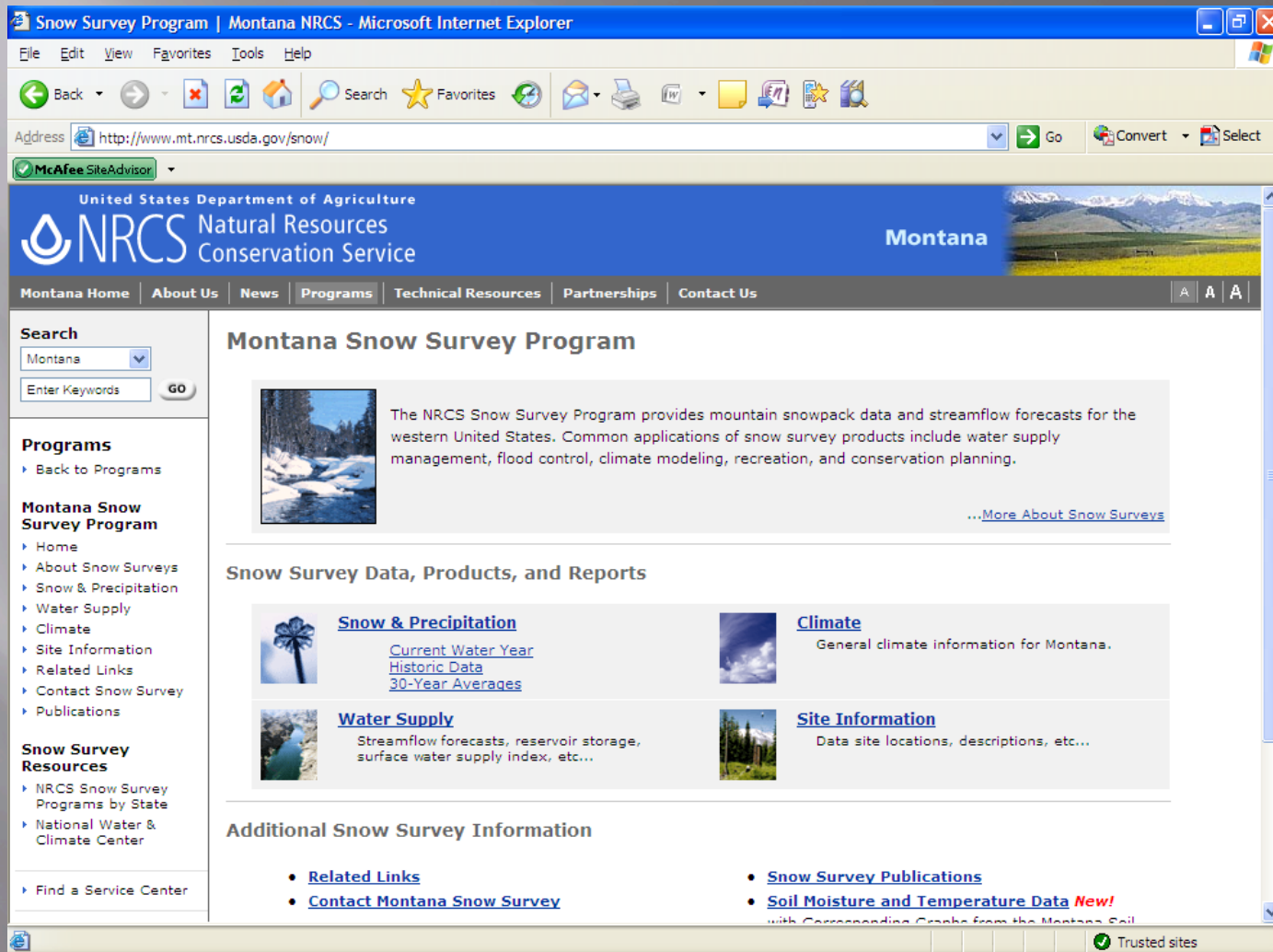
The screenshot shows a web browser window with the URL <http://www.mt.nrcs.usda.gov/snow/watersupply/peakdatetable.html>. The page is titled "Snowmelt Peak Streamflow Dates Forecast Table" and includes a disclaimer: "Snowmelt peak dates below are computed using May 26, 2010, data. These are dates for snowmelt peaks and NOT rainfall peaks that might occur after the snowmelt peaks. This information DOES NOT apply to streamflows below reservoirs. This is the final update for 2010."

The table lists the following data:

Watershed	Snowmelt Peak Flow Dates
Bitterroot River near Darby	May 19 to May 25
Bitterroot River at Missoula	May 23 to May 29
Blackfoot River near Bonner	May 20 to May 26
Clark Fork River above Missoula	May 23 to May 29
Clark Fork River at St. Regis	May 19 to May 25
Clark Fork River below Missoula	May 23 to May 29
Como Reservoir Inflow	May 21 to May 27
Fisher River near Libby	Peaked May 19
Little Blackfoot River near Garrison	May 18 to May 24
Lower Willow Creek Reservoir Inflow	May 14 to May 20
Middle Fork Flathead River near West Glacier	May 18 to May 24
Middle Fork Rock Creek near Phillipsburg	May 23 to May 29
Mill Creek near Niarada	May 16 to May 22
Nevada Creek near Helmville	May 18 to May 24

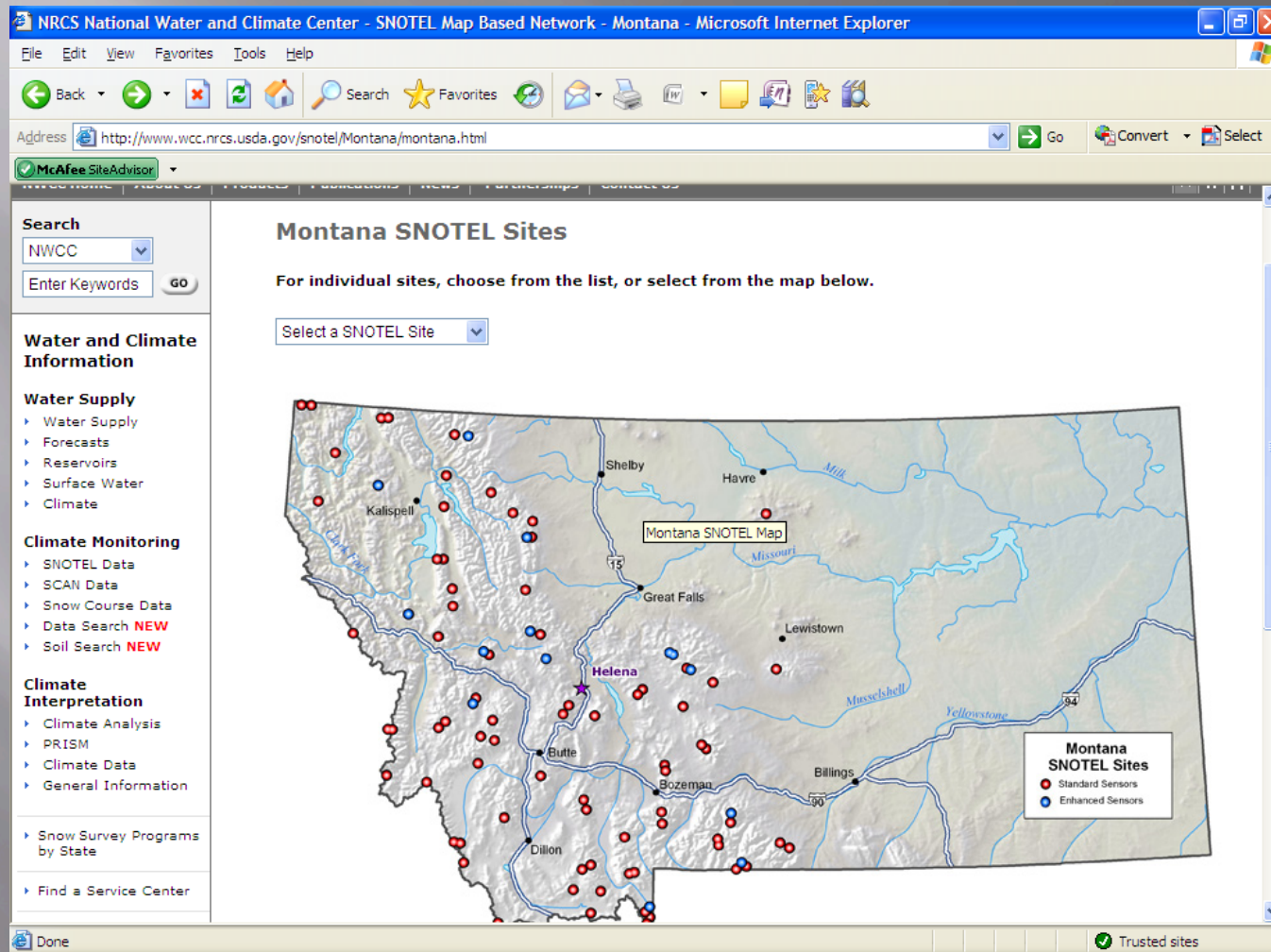
SNOTEL PRODUCTS

Web Based Services



<http://www.mt.nrcs.usda.gov/snow/>

Web Based Services (cont.)



<http://www.wcc.nrcs.usda.gov/snotel/Montana/montana.html>

Web Based Services (cont.)

Snow Survey Water Supply and Reservoir Storage Products | Montana NRCS - Microsoft Internet Explorer

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Address <http://www.mt.nrcs.usda.gov/snow/watersupply/> Go Convert Select

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NRCS Snow Survey Programs by State
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Water Supply & Reservoir Storage

Streamflow Forecasting

- [Water Supply Outlook Reports](#) (Released monthly by state, current & historic reports available)
- [Montana Streamflow Forecast Tables \(1st of Month\)](#) (Text file)
- [Montana Streamflow Forecast Charts \(1st of Month\)](#)
- [Montana Updated Volume Forecast Tables](#) (Text file)
- [Daily Guidance Streamflow Forecasts Using SNOTEL Data - NEW](#)
- Streamflow Forecast Maps for: [Montana Maps](#) | [Western US Maps](#)
- Streamflow Forecast Tables for: [Montana Maps](#) | [Western US Maps](#)
- [Streamflow Forecast Probability Charts](#) (For selected stations in each state)
- [Guide to Interpreting Streamflow Forecasts](#)
- [Snowmelt Peak Streamflow Forecast Graphs](#)
- [Snowmelt Peak Streamflow Dates Forecast Table](#)
- [Snowmelt Peak Streamflow Volume Forecast Table](#)
- [Low Flow Forecasts](#)

Reservoir Storage

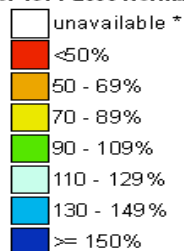
- [Current Montana Reservoir Storage Graphic](#)
- [Water Year Reservoir Storage Graphs for Montana](#) (List-based access by month)
- [Current Western US Reservoir Storage Graphic](#)
- [Historic Western US Reservoir Storage Graphics](#)

Trusted sites

Westwide SNOTEL Current Snow Water Equivalent (SWE) % of Normal

Mar 25, 2009

Current Snow Water Equivalent (SWE)
Basin-wide Percent
of 1971-2000 Normal



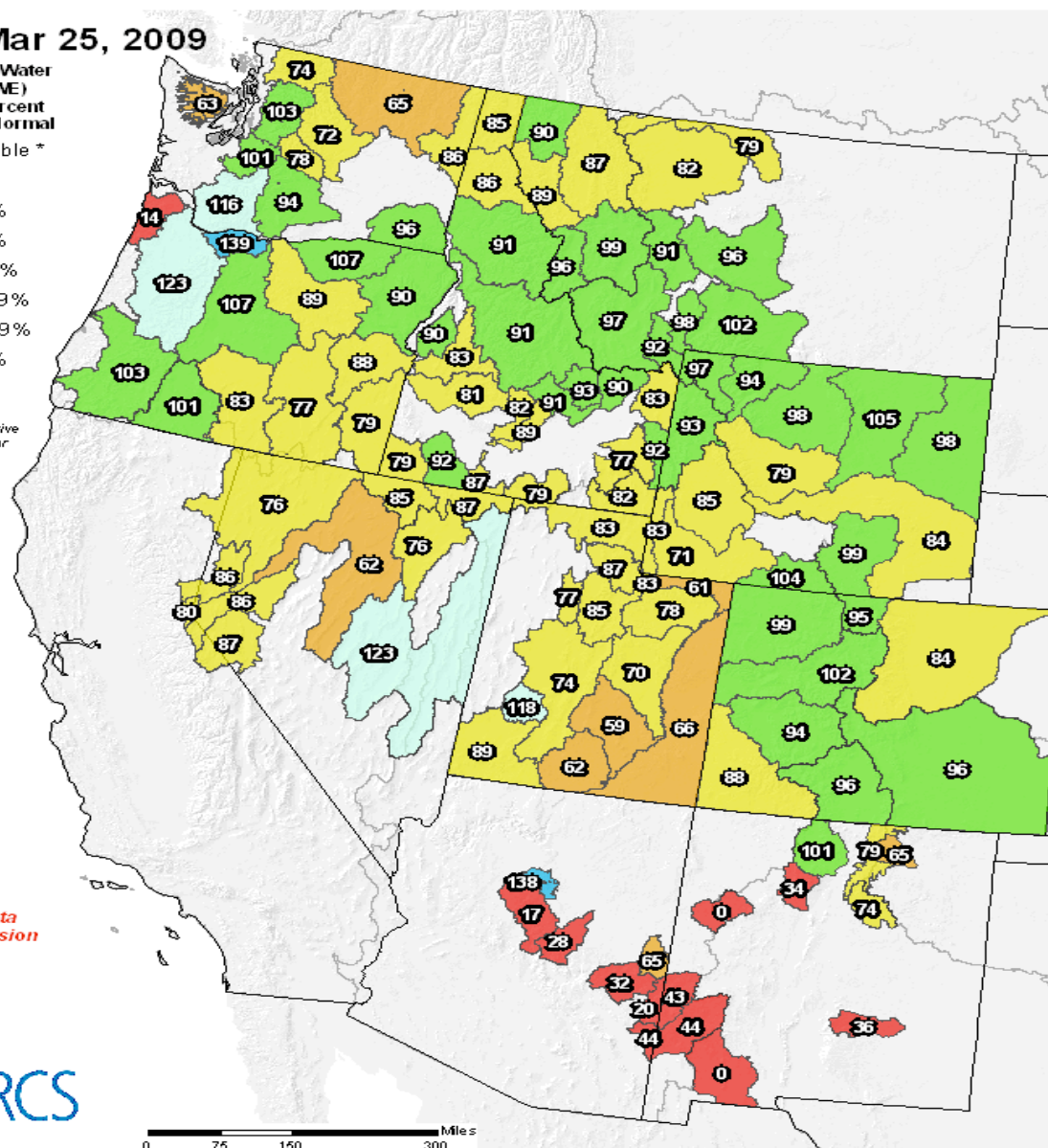
* Data unavailable
at time of posting
or measurement
is not representative
at this time of year

Provisional data
subject to revision



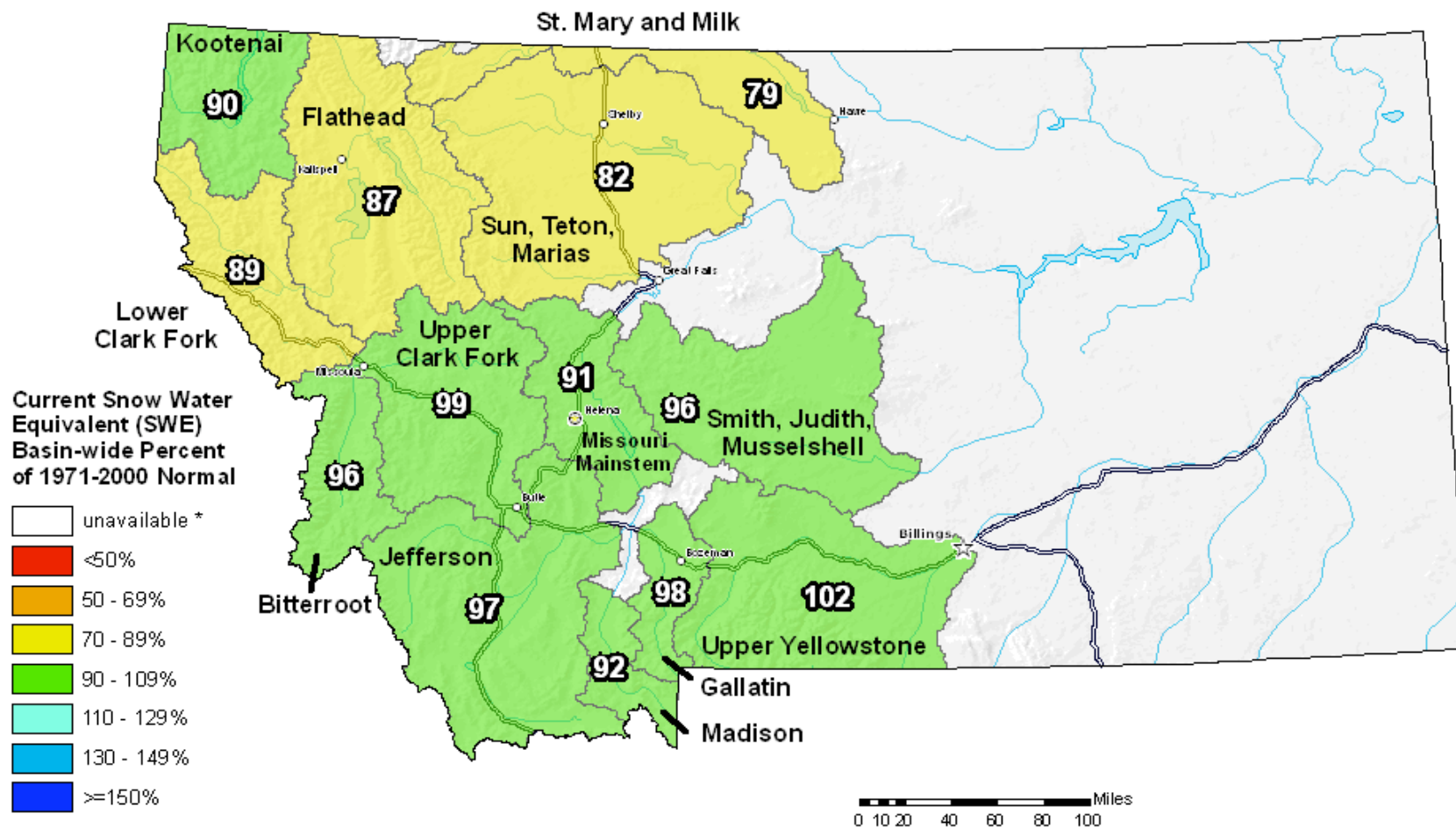
The snow water equivalent percent of normal represents the current snowwater equivalent found at selected SNOTEL sites in or near the basin compared to the average value for those sites on this day. Data based on the first reading of the day (typically 00:00).

Prepared by the USDA/NRCS National Water and Climate Center
Portland, Oregon <http://www.wcc.nrcs.usda.gov/gis/>
Based on data from <http://www.wcc.nrcs.usda.gov/reports/>
Science contact: Tom.Pagano@por.usda.gov 503 414 3010



Montana SNOTEL Current Snow Water Equivalent (SWE) % of Normal

Mar 25, 2009



* Data unavailable at time of posting or measurement is not representative at this time of year

**Provisional Data
Subject to Revision**



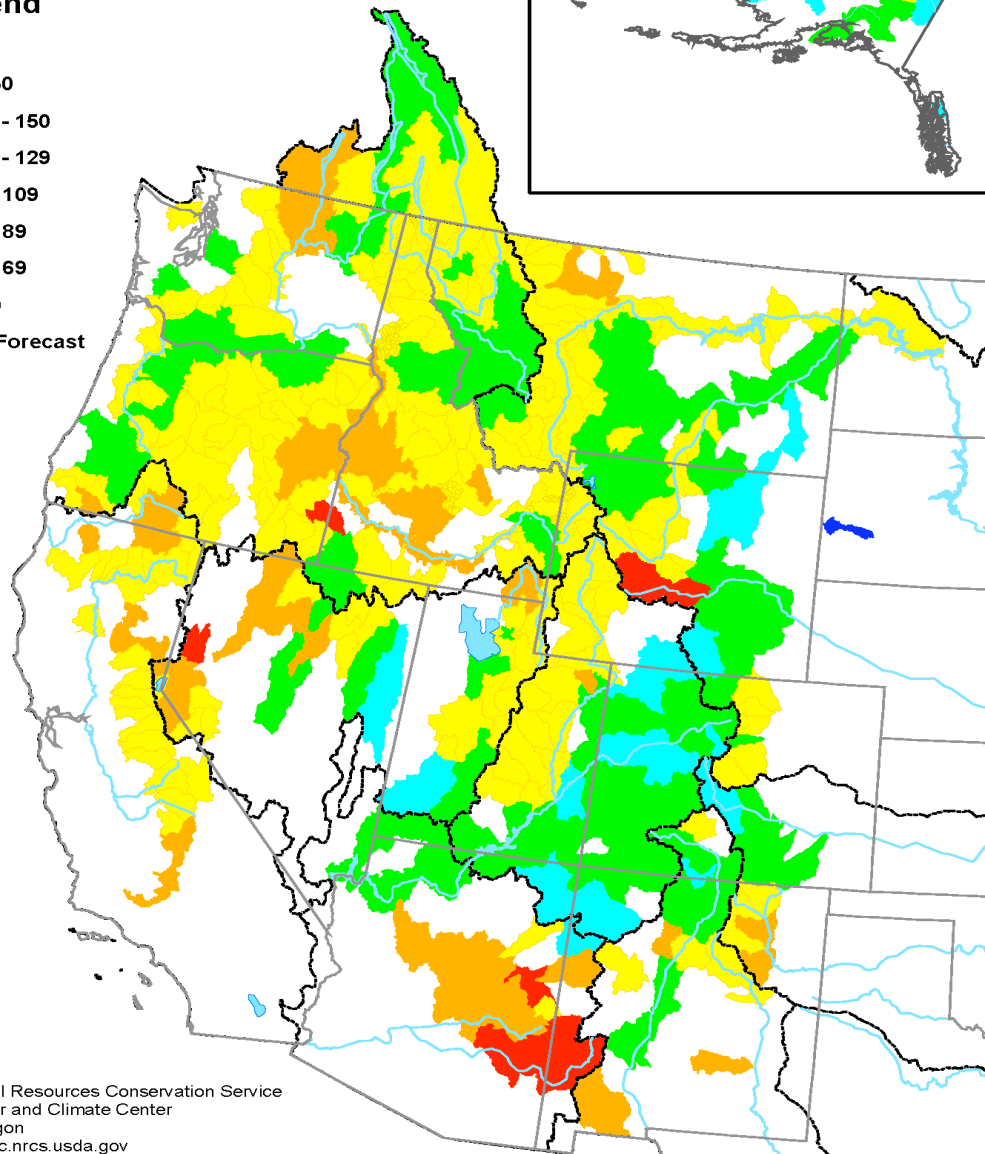
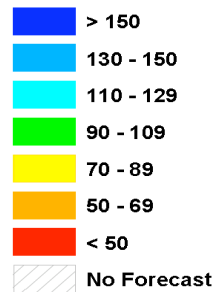
The snowwater equivalent percent of normal represents the current snowwater equivalent found at selected SNOTEL sites in or near the basin compared to the average value for those sites on this day. Data based on the first reading of the day (typically 00:00).

Prepared by the USDA/NRCS National Water and Climate Center
Portland, Oregon <http://www.wcc.nrcs.usda.gov/gis/>
Based on data from <http://www.wcc.nrcs.usda.gov/reports/>
Science contact: Tom.Pagano@por.usda.gov 503 414 3010

Spring and Summer Streamflow Forecasts as of March 1, 2009

Legend

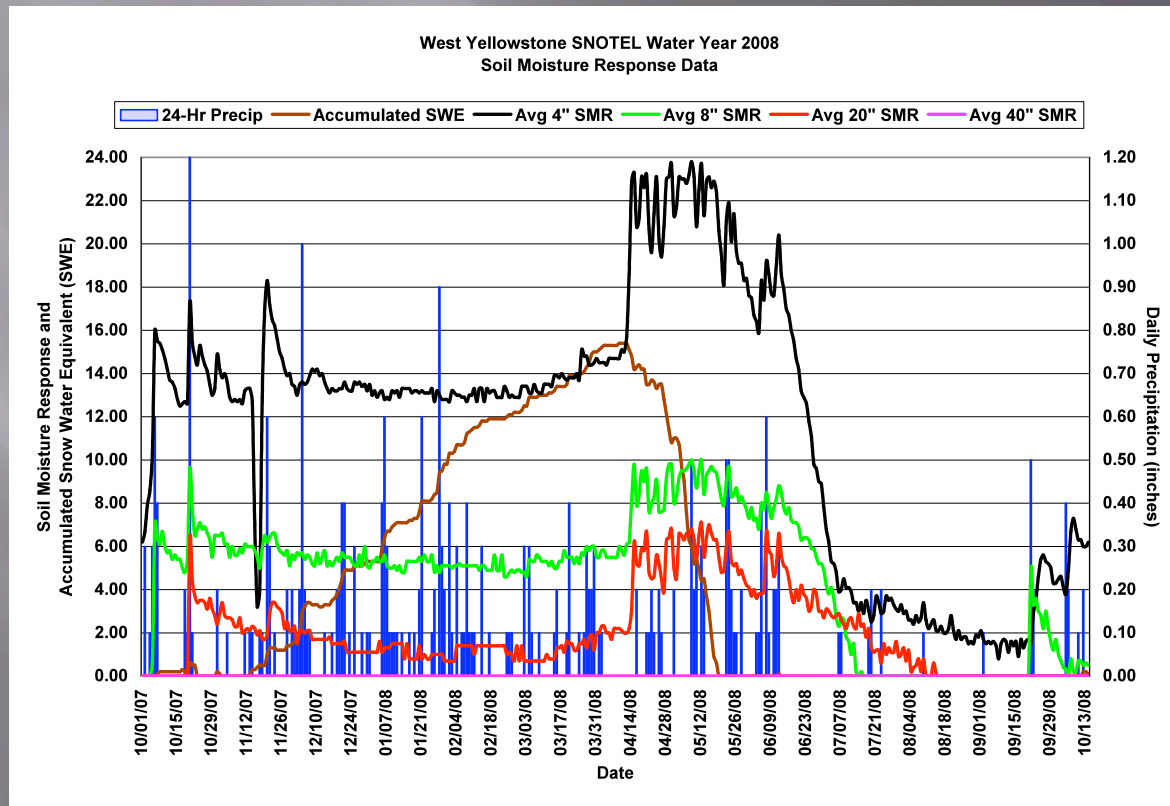
percent



Prepared by
USDA, Natural Resources Conservation Service
National Water and Climate Center
Portland, Oregon
<http://www.wcc.nrcs.usda.gov>

APPLYING NEW TECHNOLOGY TO SNOTEL SITES

Over the past three years, soil water content and soil temperature sensors have been added at select SNOTEL sites. This data will be incorporated into streamflow forecast models for antecedent and beginning of snowmelt soil moisture conditions.



Future Direction for Runoff Forecasting

- ▣ Use of ArcGIS for basin analysis in selecting future SNOTEL sites
- ▣ Incorporate Remote Sensing technologies into an physically based model system. The existing SNOTEL system provides an excellent opportunity for long term records used in ground truthing aerial sensor outputs. This will provide real-time snow conditions for an entire basin, and move away from point-in-time measurements at fixed elevations and locations. This will allow us to monitor the entire water system.
- ▣ Incorporating emerging technologies at existing SNOTEL sites such as Fiber Optic Distributed Temperature Sensing (DTS), Ground Penetrating Radar (GPR) and Lydar, Fluidless Pillows, and Satellite Communications.

Thanks for listening!

